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Stakeholder priorities for multi-functional coastal defence developments and steps to effective implementation

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27 **1. Introduction**

28 Climate change is leading to rising and stormier seas, increasing coastal erosion and flood
29 risks (IPCC 2014). In response, natural coastlines around the world are being replaced and
30 reinforced by hard engineered structures such as seawalls, breakwaters and groynes (hereafter
31 'coastal defence structures'; Koike 1996, Davis et al. 2002, Chapman and Bulleri 2003, Airolidi
32 and Beck 2007, Cooper et al. 2016). The negative environmental impacts of these structures
33 have been reasonably well-studied. In addition to direct loss and disturbance of species and
34 habitats (Martin et al. 2005, Dugan et al. 2008), coastal defences can degrade natural
35 landscapes (Burcharth et al. 2007), facilitate the spread of non-native species (Ruiz et al. 2009,
36 Mineur et al. 2012, Airolidi et al. 2015, Bishop et al. 2016, Heery et al. 2016), and alter coastal
37 processes, often with unintended knock-on effects elsewhere (Burcharth et al. 2007, Govaerts
38 and Lauwaert 2009). Further, these artificial structures tend to be poor-quality habitats,
39 supporting depauperate (Chapman 2003, Moschella et al. 2005, Firth et al. 2013b, 2016b) and
40 'non-natural' (Chapman and Bulleri 2003, Moschella et al. 2005) communities. Soft
41 engineering approaches such as beach replenishment, sand dune stabilisation and managed
42 realignment are widely considered to be more sustainable options for flood and erosion risk
43 management (Capobianco and Stive 2000, Turner et al. 2007, Govaerts and Lauwaert 2009,
44 Temmerman et al. 2013, Hanley et al. 2014). However, in scenarios where no alternative
45 options are viable for protecting people, property and infrastructure, shoreline management
46 policies continue to recommend a strategy of 'hold the line' (e.g. in the UK: Environment
47 Agency 2009). This means that local authorities will be required to maintain existing defences
48 and potentially implement additional 'hard' protection measures.

49 In order to fulfil international marine conservation commitments (laid out in the OSPAR
50 Convention and the Convention on Biological Diversity; also see Naylor et al. 2012 for an
51 outline of some relevant European and UK legal instruments), governments have begun to
52 recognise the need for more proactive marine planning policies and legislation. This study
53 focuses on UK planning policies and stakeholders, but similar challenges are being faced

54 across Europe and the world (Nicholls and Tol 2006, Hanson et al. 2011, Hinkel et al. 2014).
55 The UK's Marine Policy Statement (HM Government 2011) advises that in addition to
56 avoiding harm to marine ecology and biodiversity (§2.6.1.3), developments also “*may*
57 *provide, where appropriate, opportunities for building-in beneficial features*” (§2.6.1.4).
58 Although not prescribing a definitive obligation, this clearly advocates sensitive engineering
59 design that can deliver secondary benefits above and beyond the primary purpose of
60 developments – in the context of this study, coastal protection.

61 To date, there are few examples of truly and purposefully-designed multi-functional coastal
62 defences around the world (but see Mead and Black 1999, Harris 2003, Jackson et al. 2012,
63 Mendonça et al. 2012, Scyphers et al. 2015, Perkol-Finkel and Sella 2016). Single-purpose
64 artificial reefs have been implemented to provide habitat for commercial fish species (Santos
65 and Monteiro 1997, Spanier et al. 2010), to enhance marine biodiversity (Ambrose 1994,
66 Allemand et al. 2000), and to provide amenity functions such as surfing (Rendle and Rodwell
67 2014), diving (Wilhelmsson et al. 1998) and sea angling (Wilson 1991). Their success,
68 however, has been variable (Baine 2001, Dafforn et al. 2015). There are many similarities
69 between artificial structures designed for habitat and amenity, and those designed for coastal
70 defence, suggesting that multi-functional coastal defence structures should be viable
71 (Challinor and Hall 2008). Indeed several of these habitat and amenity services have been
72 reported to arise incidentally as secondary functions from traditional coastal defence structures
73 (e.g. Collins et al. 1994, Pister 2009). It has been argued, however, that unless designed with
74 specific objectives in mind (e.g. target species), net ecological benefits are unlikely to be truly
75 realised (Pickering and Whitmarsh 1997, Challinor and Hall 2008, Sella and Perkol-Finkel
76 2015), and recreational uses are unlikely to be compatible (e.g. Airolidi et al. 2005).
77 Nevertheless, artificial surfing reefs are increasingly being adopted for coastal protection
78 (Lokesha et al. 2013) and there is an expanding body of evidence to support the potential for
79 ecologically-beneficial designs to be incorporated into coastal defence structures (Moschella

80 et al. 2005, Chapman and Blockley 2009, Firth et al. 2013a, 2014, Perkol-Finkel and Sella
81 2014, 2016, Browne and Chapman 2014, Sella and Perkol-Finkel 2015, Evans et al. 2016).

82 Despite this known potential and policy recommendation, there remain numerous
83 impediments to implementation of multi-functional coastal defence developments – perhaps
84 as a function of the wider issue of ineffectual science-policy linkages (McNie 2007, Holmes
85 and Clark 2008, Weichselgartner and Kasperson 2010). Further research is necessary to
86 expand the knowledge base of alternative options, clarify choices and ultimately enable
87 policy-makers to achieve desired outcomes (McNie 2007). To ensure research efforts and
88 resources are invested effectively, it is first necessary to determine what secondary benefits
89 can potentially be built-in to engineered coastal developments, and further, which of these
90 benefits would be most desirable. It is unlikely that secondary benefits will be perceived in
91 the same way across different stakeholder groups (e.g. conservation groups, engineers,
92 statutory bodies and researchers; Naylor et al. 2012; see also Zanuttigh et al. 2015). Further,
93 their order of priority when evaluating different design options is unlikely to be consistent,
94 since each option will probably present a suite of compromises and trade-offs. For example,
95 the addition of pits, crevices and rock pools to intertidal artificial structures may be an
96 effective way of increasing biodiversity (Chapman and Blockley 2009, Firth et al. 2014,
97 Browne and Chapman 2014, Evans et al. 2016) and stocks of exploited species (Martins et al.
98 2010), but they may not support the same assemblages as found in natural systems (Evans et
99 al. 2016). Similarly, pre-cast concrete habitat enhancement units can be cheaply and easily
100 deployed into structures (e.g. see BIOBLOCK demonstration project in Firth et al. 2014), but
101 the net environmental benefits of enhancement using concrete, with its associated large carbon
102 footprint (Flower and Sanjayan 2007), may be reduced (Perkol-Finkel and Sella 2014).
103 Species of conservation interest can be transplanted onto structures (Clark and Edwards 1994,
104 Perkol-Finkel et al. 2012, Ng et al. 2015, Ferrario et al. 2016), but this may have implications
105 for local authorities tasked with maintaining those structures (Airoidi and Bulleri 2011). And
106 reefs that aggregate commercial fish species may economically benefit professional and/or

107 recreational fisheries (Collins et al. 1994), but they may lead to over-exploitation of
108 populations if structures attract individuals from surrounding natural habitats rather than
109 produce additional biomass (Pickering and Whitmarsh 1997). Habitat interventions may be
110 designed with specific ecological and socio-economic responses in mind, but planners are
111 required to judge the relative merits of each response in order to select the optimal design.

112 The aim of this study was to investigate stakeholder attitudes towards multi-functional coastal
113 defence developments across different sector groups. We carried out a perception study in
114 England and Wales using a traditional quantitative questionnaire and a semi-quantitative
115 modified Delphi survey (Dalkey 1969, Mukherjee et al. 2015). We targeted stakeholders in
116 England and Wales, specifically, because of the scale of the challenges regarding coastal
117 flooding and erosion (i.e. almost 40% of the coastline of England and Wales is already under
118 some form of coastal protection: Masselink and Russell 2013). The questionnaire was
119 designed to gather preliminary information about perceptions of coastal defences and the
120 potential to incorporate secondary benefits into developments (Evans 2016). A modified
121 Delphi technique was then employed to elicit detailed information and professional
122 judgements from a panel of experts and practitioners from seven different sectors. Our
123 objectives were to: (i) determine the most important considerations for planning coastal
124 defence developments and their perceived order of priority; (ii) determine the potential
125 secondary benefits that can be built-in to coastal defence developments and their perceived
126 order of priority; (iii) determine the level of support for implementing multi-functional coastal
127 defences; and (iv) identify differences and consensus in perceptions across different sector
128 groups. In light of comments received in the early stages of the Delphi study, we added a fifth
129 objective to: (v) identify the current barriers to effective implementation and steps for moving
130 forward. Here we synthesise our findings and propose a four-step process to implementation
131 of multi-functional coastal defence developments that can deliver secondary ecological and/or
132 socio-economic benefits, as recommended by environmental legislation. Although we focus
133 here on coastal defence structures, the philosophy and findings of this research may be equally

relevant for the planning and design of any other developments in the marine environment (e.g. for oil and gas exploration, renewable energy generation, navigation, mariculture, recreation) with the potential to support biodiversity and natural capital.

2. Materials and Methods

2.1 Survey instruments

A preliminary questionnaire survey was undertaken between March 2013 and September 2014 to gather scoping information about stakeholder perceptions of coastal defences and their potential to deliver secondary benefits. Questionnaires were distributed to stakeholders (SOM Table 1) and members of the public in England and Wales, and feedback was received from 118 respondents. Only one key finding from the questionnaire is presented in this paper but full details can be found in Evans (2016). Respondents were asked to indicate their level of support for traditional and then multi-functional coastal defence structures on a ten-point forced-choice (i.e. no neutral option) visual Likert scale (Allen and Seaman 2007), between ‘Not supportive at all’ and ‘Very supportive’. Responses were anonymised and coded to appropriate sector groups for analysis.

Based on insight gained from questionnaire responses (Evans 2016), a Delphi survey was devised to elicit detailed information and expert judgements regarding the desirability of secondary benefits that can be built-in to multi-functional coastal defence developments. The method is an effective yet underused and undervalued technique (Mukherjee et al. 2015) that provides an interactive communication structure between the researchers and a panel of experts with a vested interest in the problem at hand. Questions are asked over a number of rounds, and between each round, responses are analysed and fed back to the panel in an iterative process. This approach allows respondents to carefully consider and develop their answers over an extended period, in the context of rationale provided by other panel members (Garrod and Fyall 2000, 2005). Discrepancies and consensus may be identified (although consensus is not explicitly sought and will not be achieved if none exists), and information

160 can be synthesised on highly complex and subjective problems that are not easily addressed
161 using conventional questionnaires (Mukherjee et al. 2015).

162 In this study the panel consisted of 16 experts and practitioners from seven different sector
163 groups across England and Wales (Table 1). Sector groups were defined based on responses
164 received during the preliminary questionnaire survey. To ensure the expertise and perspectives
165 of panel members were relevant to the subject of research, the Local Authority panellists were
166 invited from coastal local authorities and the Statutory Bodies panellists were invited from
167 teams with a marine/coastal remit. Similarly, panel members from the Conservation,
168 Ecological and Engineering Consultant sectors all had experience in marine and coastal issues,
169 and the Academic Non-specialists were both marine scientists. Academic Non-specialists
170 were included in the study since they were anticipated to contribute an objective, critical and
171 scientifically-literate perspective to the discussion.

172

173 **Table 1** Number of Delphi panel members from each sector group.

Sector	Number of respondents
Academic Non-specialist (ANS)	2
Academic Specialist (AS)	1
Conservation (C)	2
Ecological Consultant (EcC)	2
Engineering Consultant (EnC)	2
Local Authority (LA)	2
Statutory Bodies* (SB)	5
N	16

174 *Statutory Bodies – Coastal Management and Nature Conservation

175

176 The size of the panel is not a critical feature of the Delphi technique (Smith 1995), but
177 ‘balance’ in the panel, in terms of interests and expertise, is important throughout the process
178 (Wheeller et al. 1990, Garrod 2012). There is an accepted element of judgement regarding
179 what constitutes a balanced panel (Wheeller et al. 1990, Garrod 2012). In this study, we

180 included a higher number of panel members from the Statutory Bodies sector due to the
181 diversity of organisations and remits within that sector, and the applied nature of the issues
182 being addressed.

183 Panel members were asked to commit to three survey rounds: one scoping round and two
184 convergence rounds (Green et al. 1990, Miller 2001), which were conducted over a period of
185 three months between September and December 2014. Between each round, responses were
186 analysed and summarised in synthesis reports which were returned to the panel for
187 consideration along with the next round of questions. The study was conducted via email,
188 retaining anonymity throughout. The aim of this was to avoid the risk of bias in responses
189 caused by the influence of personality or institutional allegiances (Frechtling 1996). Panel
190 members were asked to respond fully and thoughtfully and to provide rationale where
191 appropriate.

192 *2.2 Progression through preliminary rounds*

193 Results presented in this paper reflect final outcomes from a modified Delphi study, following
194 three rounds of questions. We consider this a ‘modified’ Delphi study since the wording of
195 questions and ranked lists evolved between rounds in response to feedback from the panel.
196 This precluded systematic assessment of consensus development as per a traditional Delphi
197 study (e.g. Garrod and Fyall 2000), but as a result, final outcomes were agreed (by the panel)
198 to be more meaningful and valuable for informing marine management policy and practice.
199 To place the findings in the appropriate context, it is necessary to comment on how the process
200 developed through preliminary rounds. The response rate was 100% in all three rounds of the
201 survey.

202 Round 1 (the scoping round) consisted of three open-ended questions designed to gather full
203 and detailed information on the subject of research (Box 1).

204

Box 1. Three overarching questions answered by the Delphi survey panel in Round 1

Q1. What are the most important considerations when planning coastal defence works (i.e. construction or maintenance of engineered coastal defence structures)?

Q2. What are the potential secondary benefits of engineered coastal defence structures (i.e. beyond their primary function of providing protection against flooding and erosion)?

Q3. Would you be more supportive of the construction of additional coastal defences around the UK if they were multi-functional structures (i.e. ones that deliver secondary ecological and/or socio-economic benefits)? Why?

Several major themes emerged in the responses provided to Round 1 Questions 1 and 2 (Box 1), which were organised into subthemes and synthesised into two lists of 20 considerations (*cf* Question 1, Box 1) and 20 potential secondary benefits (*cf* Question 2, Box 1) which were presented back to the panel (SOM Tables 2 and 3). In Round 2 the panel was asked to rank both lists on a priority scale between one and 20 (1 = ‘High priority’, 20 = ‘Low priority’). Several panel members commented on the difficulty of ranking a list of 20 options on one linear scale of priority and offered suggestions for reducing the lists. In response, for Question 1 (Box 1) we reduced the initial list of 20 considerations down to a new list of ten implementation-level considerations which the panel was asked to rank in Round 3 (1 = ‘High priority’, 10 = ‘Low priority’; results presented in 3.1). As part of this reduction process, considerations framed as opposite *positive* and *negative* impacts were combined into single considerations framed as *net* impacts. To account for this forfeit of detail regarding the relative importance of positive and negative impacts, we constructed a summary statement (Box 2) with which panel members were asked to indicate their level of agreement in Round 3, on a standard five-point Likert scale (1 = ‘Strongly disagree’, 2 = ‘Disagree’, 3 = ‘Neither agree nor disagree’, 4 = ‘Agree’, 5 = ‘Strongly agree’; results presented in 3.1).

Box 2. Summary Statement 1

“Considerations for avoiding/minimising negative impacts are more important than considerations for creating/maximising positive impacts.”

For Question 2 (Box 1), we split the initial list of 20 potential secondary benefits into two new lists of 15 implementation-level secondary benefits (i.e. features that could actively be built-in to hard coastal defence structures) and ten potential reasons for building them in. The panel was again asked to rank these lists in order of priority in Round 3 (1 = ‘High priority’, 15/10 = ‘Low priority’; results presented in 3.3).

Scoping round responses to Question 3 (Box 1) were used to construct six summary statements to reflect the range of opinions expressed, along with alternative opinions created for the purpose of the study. In Round 2 the panel was asked to select the statement with which they agreed most (results presented in 3.2). To investigate the potential for consensus on this issue, in Round 3 a new summary statement was constructed which combined elements of the most favoured statements from Round 2. Panel members were again asked to indicate their level of agreement with this statement on a standard five-point Likert scale (results presented in 3.2).

In Round 1, the panel provided valuable comments regarding perceived barriers to effective implementation and suggestions for moving forward. Although the survey did not explicitly seek comment on these themes, we considered this to be valuable information and therefore included additional questions to gather more complete perceptions in subsequent rounds. Several additions were put forward in Round 2, from which two lists of ten current barriers and ten suggestions for moving forward were constructed to take forward to Round 3. The panel was once again asked to rank these lists in order of priority (1 = ‘High priority’, 15/10 = ‘Low priority’; results presented in 3.4).

254 In response to concerns raised in previous rounds, in Round 3 the panel was explicitly asked
255 to consider potential secondary benefits “*as beneficial features of a hard defence structure*
256 *evaluated against the same hard defence structure without the added beneficial features*” (i.e.
257 not against alternative coastal management strategies). They were also asked to assume that
258 “*the secondary benefits can be built-in to structures with no compromise of primary function*
259 *or additional negative impacts, and that they can achieve their intended purpose*”.

260 2.3 Data analysis

261 Visual Likert scale responses collected via the preliminary questionnaire were converted to
262 scores between one and ten (1 = low, 10 = high), assuming even spacing between the ten-point
263 scale intervals (Allen and Seaman 2007). A Wilcoxon Signed Ranks test was used to test for
264 differences between overall median levels of support for traditional and multi-functional
265 coastal defence structures. This non-parametric test was used because of non-normality in
266 scores. One-way analysis of variance (ANOVA) was used to test for differences in the mean
267 levels of support for traditional and multifunctional structures, and the *difference* in levels of
268 support for each, between sector groups. Student-Newman-Keuls post-hoc tests were used to
269 identify pairwise significant differences. Analyses were carried out in SPSS (IBM Corp.
270 Version 21, 2012).

271 In the Delphi study, scoping round (Round 1) responses were coded using NVivo qualitative
272 data analysis software (QSR International Pty Ltd. Version 10, 2014) and organised into
273 overarching themes and subthemes for each question. Themes and subthemes were then
274 translated into lists of options for ranking in subsequent rounds.

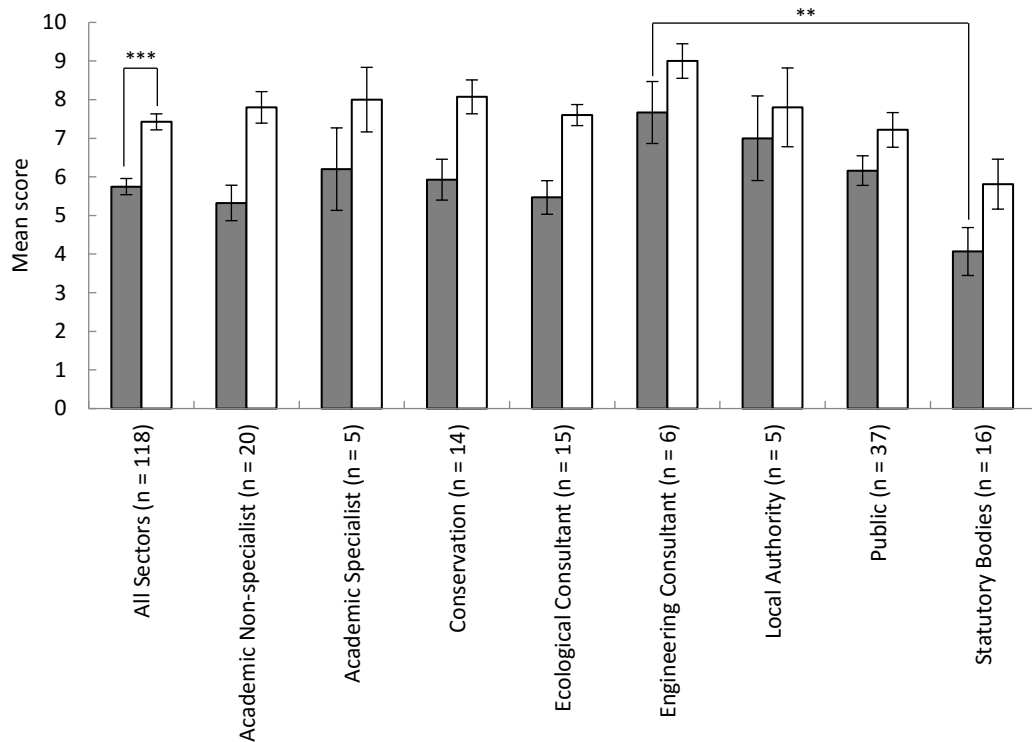
275 In convergence rounds (Rounds 2 and 3), individual ranks assigned by panel members were
276 converted to scores on an inverted scale between one and the number of options available for
277 ranking n (1 = low, n = high). Scores were summed over responses from the whole panel, and
278 also over responses provided by panel members from each of the seven sectors separately.
279 Total scores were then converted back into overall priority rankings between one and n (1 =

280 'High priority', n = 'Low priority'). Box and whisker plots of median scores, interquartile
281 ranges and outliers (i.e. ranks lying outside 1.5 times the interquartile range) were plotted to
282 visually assess the level of consensus among the panel.

283 3. Results

284 Questionnaire responses collectively indicated significantly increased levels of support for
285 additional coastal defence structures in the UK *if they were multi-functional structures*
286 (Wilcoxon $Z = -7.377$, $P < 0.001$) (Figure 1). The magnitude of increase was consistent across
287 all sectors ($F_{7,117} = 1.250$, $P = 0.282$). Respondents from the Statutory Bodies sector indicated
288 the lowest mean levels of support for both standard (4.1 ± 0.6 SE) and multi-functional
289 structures (5.8 ± 0.7 SE), whilst respondents from the Engineering Consultant sector indicated
290 the highest levels of support (7.7 ± 0.8 SE and 9.0 ± 0.5 SE, respectively). The difference in
291 support for additional (non multi-functional) coastal defence structures between these two
292 sectors was significant ($F_{7,117} = 2.578$, $P = 0.017$; SNK $P < 0.05$; no other significant
293 differences were found).

294



295

296 **Figure 1** Level of support for additional coastal defence structures (grey bars) and additional
 297 multi-functional coastal defence structures (white bars), as indicated by mean scores (\pm SE; n
 298 = 118) assigned by questionnaire respondents on a scale of 1 to 10 (1 = ‘Not supportive at all’,
 299 10 = ‘Very supportive’). Significant differences are indicated (**: $p < 0.05$, ***: $p < 0.001$).

300

301 3.1 Most important considerations when planning coastal defence developments

302 In the Delphi study Round 3 Question 1, the panel was asked to rank ten considerations for
 303 planning coastal defence works: firstly based on the *current* order of priority in practice (Table
 304 2, ‘Panel¹’), and secondly based on what they thought the order of priority *should* be (Table
 305 2, ‘Panel²’). Panellists were given the option of not completing the ranking for the former
 306 (Panel¹) if they felt unqualified to do so. Twelve panel members provided answers, four of
 307 whom indicated that they felt somewhat unqualified but had provided their best-informed
 308 guess. The overall order of priority was the same regardless of whether these data were
 309 included or excluded. Unsurprisingly, the panel ranked ‘Essential criteria’ as the most
 310 important consideration. They then ranked ‘Cost’, followed by ‘Net socio-economic impacts
 311 on local communities and businesses’, followed by ‘Net ecological impacts’ as the next

312 highest current priorities in turn, but indicated that ‘Net ecological impacts’ *should* be
313 considered more important than ‘Net socio-economic impacts’, and both *should* be considered
314 more important than ‘Cost’. At the bottom end of the scale, ‘Carbon footprint’, ‘Opportunities
315 for research and development’ and ‘Opportunities for education and outreach’ were ranked as
316 the lowest priorities currently. The panel indicated, however, that ‘Carbon footprint’ and
317 ‘Opportunities for research and development’ *should* be given higher priority than ‘Level of
318 community support’ and ‘Net culture and heritage impacts’.

319 **Table 2** Considerations for planning coastal defence works in order of priority, as indicated by combined rankings of the Delphi panel (Panel¹ = perceived
320 *current* order of priority, Panel² = *preferred* order of priority) and by combined rankings (*preferred* order of priority) of panel members from different sectors
321 (1 = high, 10 = low).

CONSIDERATIONS	Panel ¹	Panel ²	ANS	AS	C	EcC	EnC	LA	SB
Essential criteria (i.e. part of a sustainable strategy, justification, in line with environmental legislation and planning guidelines, public safety, fit-for-purpose, no unintentional alteration to coastal processes, affordable/funding available)	1	1	1	1	1=	1	1	1	1
Cost (i.e. assuming funding is available)	2	4	4	4	10	3	3=	2=	6
Net socio-economic impacts on local communities and businesses (i.e. assuming minimum requirements are met and not including risk reduction from primary defence function: e.g. reduced/enhanced amenity, recreation, fisheries, navigation, tourism, employment, etc.)	3	3	3	3	5	4	3=	2=	3
Net ecological impacts (i.e. assuming minimum requirements are met and not including risk reduction from primary defence function: e.g. loss/disturbance of habitats/species, dispersal of invasive non-native species, extraction of raw materials, novel habitat/refuge for exploited species or species of conservation interest, etc.)	4	2	2	2	1=	2	2	2=	2
Net landscape impacts (i.e. assuming minimum requirements are met)	5	5	5=	6	6=	5	5	5=	5
Level of community support (i.e. assuming minimum requirements are met)	6	8	7	5	6=	6=	6	7	9
Net culture and heritage impacts (i.e. assuming minimum requirements are met and not including risk reduction from primary defence function: e.g. loss/damage of heritage features or archaeology, platform for art installations, etc.)	7	9	9	7	6=	8	7=	5=	8
Carbon footprint (i.e. assuming minimum requirements are met: e.g. processing and transport of raw materials, construction emissions, etc.)	8	6	8	8	3	9	7=	9	4
Opportunities for research and development (e.g. new engineering designs, experimental units to investigate marine/coastal ecology)	9	7	5=	10	4	6=	7=	8	7
Opportunities for education and outreach (e.g. platform for environmental education, etc.)	10	10	10	9	6=	10	10	10	10

322 ANS: Academic Non-specialist; AS: Academic Specialist; C: Conservation; EcC: Ecological Consultant; EnC: Engineering Consultant; LA: Local Authority; SB: Statutory Bodies

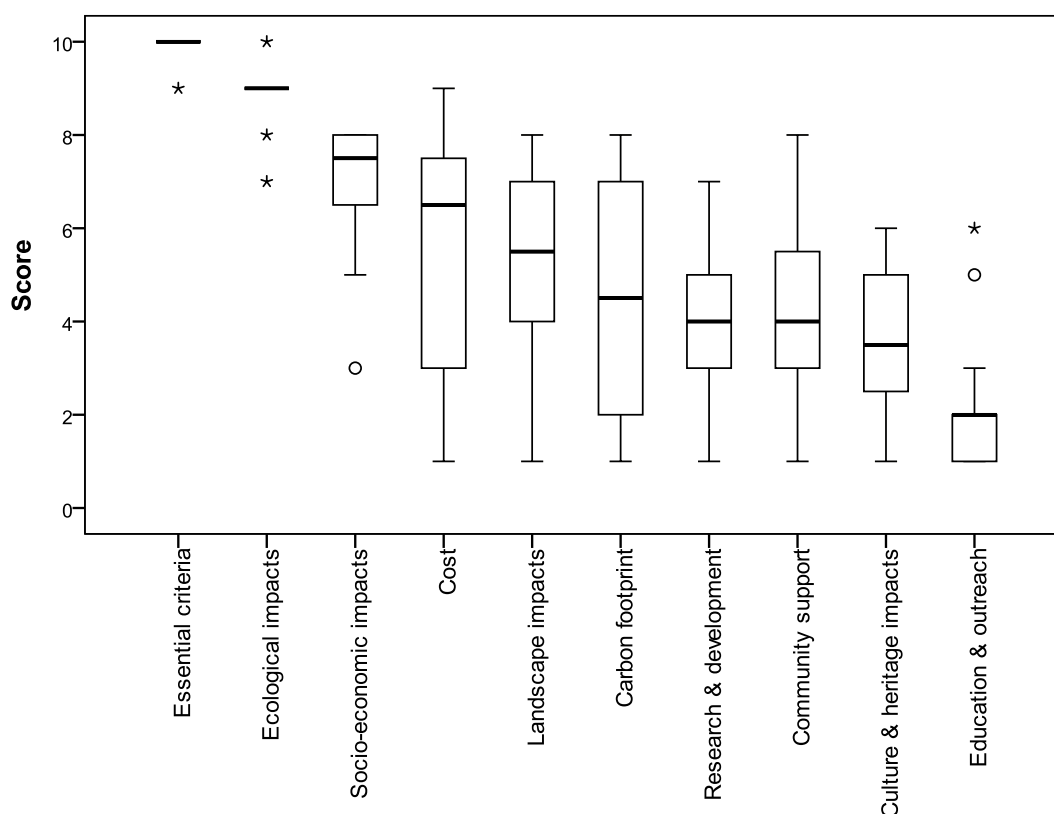


Figure 2 Median scores (inverted ranks in *preferred* order of priority, i.e. 10 = high, 1 = low) assigned to considerations for planning coastal defence works by the Delphi panel, with interquartile ranges (box), maximum/minimum scores (whiskers), outliers > 1.5 x interquartile range (○) and extreme outliers > 3 x interquartile range (★).

There was a relatively high degree of consensus for the panel's highest and lowest rankings of how considerations *should* be prioritised (Figure 2). However, there was very little consensus regarding the middle ranks such as 'Cost', 'Landscape impacts', 'Carbon footprint' and 'Community support'. Panel members from the Conservation sector and the Statutory Bodies sector perceived 'Cost' to be less important than those from other sectors (Table 2); in fact, panel members from the Conservation sector collectively ranked it as their lowest priority. Views expressed on 'Cost' varied widely, for example:

"I believe all of the considerations listed ... to be of greater importance than the overall cost of the coastal defence works."

(Statutory Bodies)

339 *“In an ideal world the cost of defence structures would not be as important as their*
340 *primary functionality ... and their net ecological impacts.”*

341 (Academic Non-specialist)

342 *“[Cost] is still sort of fixed and I’m not sure you can rank it.”*

343 (Local Authority)

344 *“We are in very challenging financial times and the drivers around any capital spend*
345 *have to be set against this background.”*

346 (Statutory Bodies)

347 Panel members from the Conservation and Statutory Bodies sectors ranked ‘Carbon footprint’
348 higher than the rest of the panel, and the Conservation sector also ranked ‘Opportunities for
349 education and outreach’ (lowest priority overall) higher than the rest of the panel. It was
350 suggested that:

351 *“We can only change perception of FCERM [Flood and Coastal Erosion Risk*
352 *Management] if education is built in better to schemes.”*

353 (Statutory Bodies)

354 To investigate the relative importance of associated positive and negative impacts on ecology
355 and local communities (in the context of planning coastal defence developments), we
356 constructed a summary statement with which panel members were asked to indicate their level
357 of agreement (Box 2).

358 Fifteen out of 16 panel members indicated that they ‘Agree’ or ‘Strongly Agree’ that
359 considerations for avoiding/minimising negative impacts are more important than
360 considerations for creating/maximising positive impacts. Some panel members raised
361 concern, however, regarding the generality of the statement. For example:

362 *“Certainly for ecology and coastal processes – not sure if this necessarily applies to*
363 *businesses.”*

364 (Local Authority)

365 One panellist from the Statutory Bodies sector indicated that they ‘Strongly Disagree’ with
366 the statement, commenting that:

367 “Any new structure will have a negative impact, just avoiding/minimising is not really
368 good enough, the aim should be to do something better.”

369 (Statutory Bodies)

370

371 *3.2 Level of support for implementing multi-functional coastal defence structures*

372 To assess the level of stakeholder support for the concept of multi-functional coastal defence
373 developments, in Round 2 Question 3 the panel was asked to indicate with which of six
374 summary statements they agreed most (Figure 3). Largely, opinion was divided between
375 Statements 5 and 4, reflecting caveated support for multi-functional structures, and Statement
376 2, reflecting more general support for multi-functional structures *if* new structures are deemed
377 necessary. One panel member from the Statutory Bodies sector selected Statement 1,
378 reflecting lack of support for hard structures regardless of multi-functionality, citing concerns
379 about unsustainable long-term coastal management. In contrast, several panel members
380 expressed disagreement with this statement (and with Statements 6 and 2), suggesting that in
381 certain scenarios hard defences are necessary and part of the strategic approach to flood and
382 coastal erosion risk management. Several panel members indicated that their opinions would
383 be better-represented by a combination of two or more statements. In particular, Statement 4
384 was frequently referred to as a second choice by those who selected Statement 5, and vice
385 versa.

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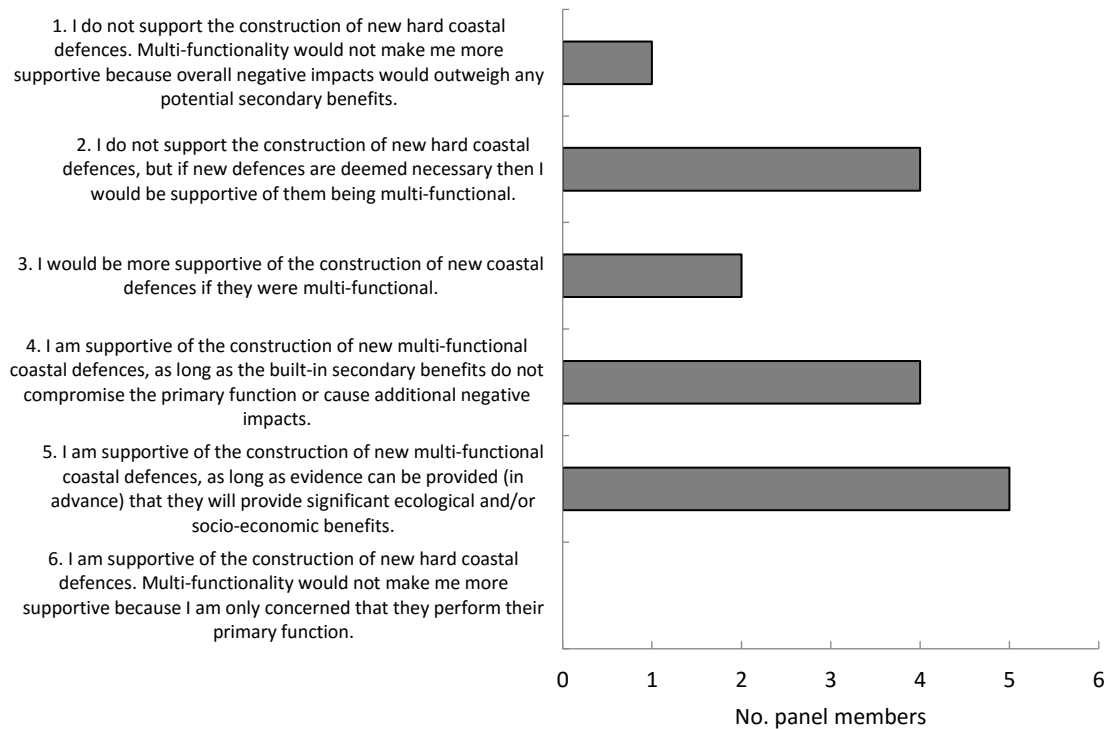


Figure 3 Frequency of selection for each of six summary statements by the Delphi panel. Panel members were asked to select the statement with which they agreed most.

Moving forward to Round 3, we constructed a new summary statement that combined elements of the most favoured statements from Round 2, and did not include any reference to support or non-support of hard coastal defences in general (Box 3). Fifteen out of 16 panel members indicated that they ‘Agree’ or ‘Strongly Agree’ that they would be more supportive of hard coastal defence structures (where deemed necessary) being multi-functional structures, as long as the two caveats in Summary Statement 2 (Box 3) were satisfied.

Box 3. Summary Statement 2

“Where hard coastal defence structures are deemed necessary, I would be more supportive of them being multi-functional structures, as long as built-in secondary benefits do not compromise primary defence function or cause additional negative impacts, and evidence can be provided that intended ecological and/or socio-economic benefits will be realised.”

406 One panel member from the Engineering Consultant sector selected ‘Neither Agree nor
407 Disagree’, commenting that:

408 *“It is important to demonstrate that there is a benefit from an engineering perspective*
409 *too, some positive feedback that makes the structure perform better.”*

410 (Engineering Consultant)

411 Two panel members also felt that the statement should specify that:

412 *“The secondary benefits should be of a reasonable cost.”*

413 (Local Authority)

414 and that any additional cost would need to be:

415 *“in proportion to the effect/evidence.”*

416 (Statutory Bodies)

417 Conversely, three panellists (from the Conservation, Academic Non-specialist and Statutory
418 Bodies sectors) felt that the statement was too constrained by the need to provide evidence,
419 which may be an unreasonable obstacle to implementation. It was suggested that:

420 *“There will always be a level of uncertainty ... [but] this should not be a reason NOT*
421 *to design structures with secondary aims in mind.”*

422 (Academic Non-Specialist)

423 Instead, based on existing evidence from other areas:

424 *“There should be a presumption that there will be some positive effect.”*

425 (Statutory Bodies)

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428 *3.3 Potential secondary benefits that can be built-in to coastal defence structures (and*
429 *motivations for building them in)*

430 In Round 3 Question 2 the panel ranked ‘Habitat for natural rocky shore communities’,
431 ‘Habitat for species of conservation interest’ and ‘Refuge for exploited species’ as the highest
432 priority secondary benefits that could be built-in to multi-functional coastal defence structures
433 (Table 3, ‘Panel’). At the bottom end of the scale, the panel perceived ‘Opportunities for
434 education and outreach’, ‘Enhanced landscape value’ and ‘Enhanced culture and heritage
435 value’ as the lowest priorities. Accordingly, the panel indicated that ‘Positive ecological
436 impacts’, ‘Divert pressure from natural systems’ and ‘Positive socio-economic impacts on
437 local communities and businesses’ were the primary motivations for implementing multi-
438 functional designs in coastal defence developments. ‘Culture and heritage’, ‘Education and
439 outreach’ and ‘Reduce carbon footprint’ were of least concern (Table 4, ‘Panel’).

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449 **Table 3** Potential secondary benefits that can be built-in to multi-functional coastal defence structures in order of priority, as indicated by combined rankings
 450 of the Delphi panel and by combined rankings of panel members from different sectors (1 = high, 15 = low).

SECONDARY BENEFITS	Panel	ANS	AS	C	EcC	EnC	LA	SB
Habitat for natural rocky shore communities (e.g. build-in microhabitat complexity and use materials suitable for natural rocky shore communities)	1	2	9	4	1	1=	5	1
Habitat for species of conservation interest (e.g. build-in habitat suitable for wintering birds, BAP species, etc.)	2	4=	5	1=	5	1=	2	3
Refuge for exploited species (e.g. build-in refuge habitat suitable for exploited species to allow populations to persist)	3	4=	7	1=	2=	9=	6	2
Habitat heterogeneity in structure design (e.g. build-in mosaic of habitats such as rocky substrate, sediments, saltmarsh patches, etc.)	4	1	6	5	2=	4	3=	5
Enhanced commercial fisheries (e.g. build-in refuge/nursery habitat for commercial species)	5	3	3	7	6=	5=	3=	8
Safeguarded biosecurity (e.g. build-in features to remove/reduce competitive advantage of non-native invasive species)	6	8=	4	3	4	15	7	7
Enhanced amenity/recreation (e.g. build-in surf reef design, promenade, beach access, recreational fishing platform, etc.)	7=	10	1	13	8=	3	1	12
House other technologies (e.g. build-in turbines, masts, etc.)	7=	11	2	8=	6=	9=	8	6
Mariculture opportunities (e.g. build-in facilities for mussel/macroalgae culture)	9	4=	8	10	13	13=	9	4
Reduced carbon footprint (e.g. use novel low-carbon materials or recycled waste materials)	10	12	11	8=	11=	5=	14	9
Opportunities for research and development – new engineering solutions (e.g. trial novel materials and structural designs)	11	7	10	11=	11=	8	10	13=
Opportunities for research and development – investigating marine/coastal ecology (e.g. build-in experimental mesocosm units)	12	8=	14	6	10	11	11=	13=
Enhanced landscape value (e.g. use natural materials, subtle design or aesthetically-attractive design)	13	13	15	14	8=	5=	11=	10
Opportunities for education and outreach (e.g. build-in facilities for public engagement or environmental education)	14	14=	13	11=	14	13=	15	11
Enhanced culture and heritage value (e.g. build-in art installations)	15	14=	12	15	15	12	13	15

451 ANS: Academic Non-specialist; AS: Academic Specialist; C: Conservation; EcC: Ecological Consultant; EnC: Engineering Consultant; LA: Local Authority; SB: Statutory Bodies

452 **Table 4** Potential reasons for building-in secondary benefits to coastal defence structures in order of priority, as indicated by combined rankings of the Delphi
453 panel and by combined rankings of panel members from different sectors (1 = high, 10 = low).

REASONS FOR BUILDING-IN SECONDARY BENEFITS	Panel	ANS	AS	C	EcC	EnC	LA	SB
Positive ecological impacts (i.e. through enhanced connectivity/resilience of rocky habitats, habitat for exploited species, habitat for species of conservation concern, habitat heterogeneity, etc.)	1	1	3	1	1	2=	2=	1
Divert pressure from natural systems (i.e. by providing access for recreation, fisheries, research, co-location with other technologies etc.)	2	2=	1	2=	2	5	4	4
Positive socio-economic impacts on local communities and businesses (i.e. through enhanced amenity, recreation, fisheries, navigation, tourism, employment, etc.)	3	2=	2	8	3	2=	2=	2=
Increase likelihood of scheme progression (i.e. by fostering public support and improving partnership funding potential)	4	4=	5	7	9	4	1	5
Reduce maintenance requirements (i.e. by building-in positive feedback in stability of structure)	5	7	4	6	6=	1	5	8
Research and development (i.e. gather evidence necessary for moving forward with multi-functional coastal defences by trialling novel engineering designs and improving knowledge of marine/coastal ecology)	6	4=	9	4	4	6=	6	6
Enhance/safeguard landscape (i.e. by using natural materials, subtle design or aesthetically-attractive design)	7	4=	10	9	5	6=	7=	2=
Reduce carbon footprint (i.e. by using low carbon technology, recycled materials, etc.)	8	9=	6	2=	6=	8	9	7
Education and outreach (i.e. by building-in facilities for public engagement and environmental education)	9	9=	8	5	8	10	10	9
Culture and heritage (i.e. by building-in art installations, etc.)	10	8	7	10	10	9	7=	10

454 ANS: Academic Non-specialist; AS: Academic Specialist; C: Conservation; EcC: Ecological Consultant; EnC: Engineering Consultant; LA: Local Authority; SB: Statutory Bodies

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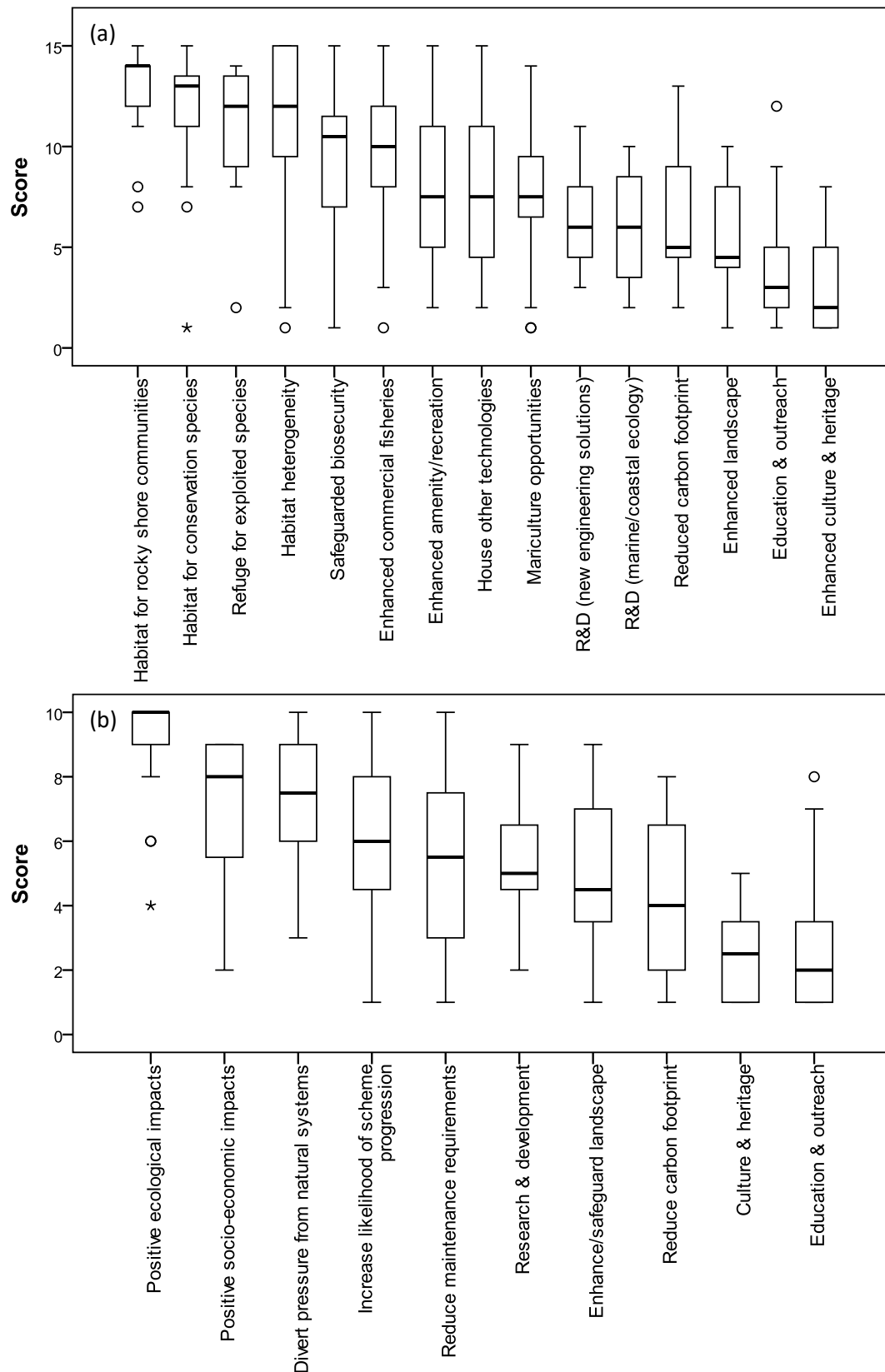


Figure 4 Median scores (inverted ranks, i.e. 15/10 = high, 1 = low) assigned to (a) potential secondary benefits and (b) reasons for building them into developments by the Delphi panel, with interquartile ranges (box), maximum/minimum scores (whiskers), outliers > 1.5 x interquartile range (○) and extreme outliers > 3 x interquartile range (*).

There was a reasonable level of consensus in what the panel ranked as the highest and lowest secondary benefits (Figure 4a) and reasons for building them into developments (Figure 4b). There was little agreement regarding the middle ranks. With regard to secondary benefits (Table 3), the Academic Specialist assigned their top ranks differently to the rest of the panel, prioritising socio-economic and technical benefits (i.e. ‘Enhanced amenity/recreation’, ‘House other technologies’ and ‘Enhanced commercial fisheries’) above the more direct ecological benefits. They suggested that if socio-economic secondary benefits are prioritised, then ecological ones can still be built-in around them.

Panel members from the Local Authority and Engineering Consultant sectors also ranked ‘Enhanced amenity/recreation’ high, whereas those from the Conservation and Statutory Bodies sectors ranked this particularly low. Panel members from the Conservation sector instead favoured ‘Safeguarded biosecurity’, as did the Academic Specialist and Ecological Consultants, whereas the Engineering Consultants ranked this as their lowest priority. The Engineering Consultants also ranked ‘Refuge for exploited species’ lower than the rest of the panel, but instead prioritised ‘Reduced carbon footprint’ and ‘Enhanced landscape value’. Finally, panel members from the Academic Non-specialist and Statutory Bodies sectors ranked ‘Mariculture opportunities’ higher than the panel as a whole. Some considered this as an opportunity for co-location of marine activities, akin to ‘House other technologies’, and ranked it high:

“given the increasingly busy state of the seas.”

(Statutory Bodies)

Others, however, were sceptical of the viability of this secondary benefit:

“due to differences in the scale of the operation and the optimal location for such activities.”

(Academic Non-Specialist)

and raised concern about:

“introductions of species novel to the system.”

(Ecological Consultant)

This latter concern was shared by several panel members in relation to some of the highest ranking ecological benefits, i.e. ‘Habitat for natural rocky shore communities’, ‘Habitat for species of conservation interest’ and ‘Habitat heterogeneity in structure design’. The importance of site-specific decision-making was a clear message from the panel throughout the process – any potential ecological benefits must be evaluated in the context of local natural habitats.

When ranking reasons for building-in benefits (Table 4), panel members from the Engineering Consultant and Local Authority sectors assigned their highest priority differently to the rest of the panel, prioritising ‘Reduce maintenance requirements’ and ‘Increase likelihood of scheme progression’, respectively. Panellists from both of these sectors nevertheless ranked ‘Positive ecological impacts’ and ‘Positive socio-economic impacts’ joint second, indicating agreement with the overall panel perception that these are primary motivations for building-in secondary benefits. In contrast, panel members from the Conservation and Ecological Consultant sectors assigned particularly low priority to ‘Increase likelihood of scheme progression’. One panel member commented that:

“If a defence structure is being planned it is a necessity in whatever form decided upon ... therefore, I believe it is not a case that it will progress any faster/smoothen as a result of added enhancements.”

(Ecological Consultant)

Panellists from the Conservation sector also ranked ‘Positive socio-economic impacts’ much lower than the rest of the panel. Instead they prioritised ‘Reduce carbon footprint’, ‘Research and development’ and ‘Education and Outreach’. Academic Non-specialists and Ecological Consultants also ranked ‘Research and development’ higher than the rest of the panel, whereas the Academic Specialist again ranked this low. There was little agreement in ranks assigned to ‘Enhance/safeguard landscape’: although panel members from the Academic Non-specialist, Ecological Consultant and Statutory Bodies sectors ranked it fairly highly, it was lowest priority for the Academic Specialist as they felt it was not a tangible secondary benefit. Also at the bottom of the rankings, ‘Culture and heritage’ and ‘Education and outreach’ were consistently perceived as low priority considerations for secondary

benefits. Rationale for this was provided by some panel members, including that there are more appropriate places to cater for these activities, and also that it is difficult to value them and identify a beneficiary through which to balance associated costs.

3.4 Current barriers to effective implementation of multi-functional coastal defences

In Round 3 Question 3 the panel was asked to rank ten current barriers to effective implementation of multi-functional coastal defence structures and ten suggestions for moving forward, in order of priority (Table 5). Several panel members commented, however, that all of the barriers and suggestions were pertinent, and little consensus was apparent in the rankings (SOM Figure 1). Others commented on the logical order in which barriers and suggestions for moving forward should be addressed. We utilised these comments to propose a four-step process to effective implementation of multi-functional coastal defence developments (Box 4), which we discuss further below.

Table 5 Current barriers to implementation and suggestions for moving forward with multi-functional coastal defence structures in order of priority, as indicated by combined rankings of the Delphi panel (1 = high, 10 = low).

CURRENT BARRIERS TO EFFECTIVE IMPLEMENTATION	Panel
Developments driven by cost and funding priorities	1
Lack of policy drive and legislative support	2
Ability to justify additional costs	3
Reliable assessment of value	4
Awareness of / engagement with the concept of multi-functionality	5
Lack of evidence that benefits will be realised	6
Poor communication between sectors during planning	7
Lack of well-understood 'products' (i.e. ecological engineering solutions)	8
Lack of understanding of ecology of manmade habitats	9
Lack of collaboration with EU/international partners (i.e. knowledge exchange)	10
SUGGESTIONS FOR MOVING FORWARD	Panel
Consider multi-functional designs in the planning stage of new defences	1
Strengthen legislative framework	2
Conduct cost-benefit analyses of potential secondary benefits	3
Conduct experimental trials to gather additional evidence	4
Make additional resources available to cover cost of multi-functional features	5
Improve awareness and engagement amongst relevant sectors	6
Develop 'products' that can be incorporated into scheme designs	7=
Develop new technologies to improve potential of multi-functional structures	7=
Expand beneficiary pays principal to include secondary benefits	9
Collaborate with EU/international partners (knowledge exchange)	10

4. Discussion

4.1 General consensus on priorities for coastal defence developments

Effective flood and coastal erosion risk management demands negotiation of many complex and conflicting stakeholder priorities. It is clear that stakeholders from different sectors have disparate personal and professional opinions on how coastal defence developments should be delivered. Nevertheless, the preliminary questionnaire survey indicated unanimous support for implementing multi-functional coastal defence structures in place of traditional single-purpose ones. The modified Delphi study revealed a more nuanced and caveated level of support, but further elicited some general consensus in terms of perceived highest and lowest priorities, despite the diverse panel composition with experts and practitioners from seven different sectors.

In general, the most important considerations for planning coastal defence developments (after ensuring essential criteria are met) were perceived to be their net ecological impacts and net socio-economic impacts on local communities and businesses. When asked about potential secondary benefits that could be built-in to developments, the Delphi panel favoured ecological benefits over social, economic and technical ones. Accordingly, primary motivations for incorporating secondary benefits were to deliver positive ecological and socio-economic impacts for the local environment and communities. There was, however, general agreement that it is more important to avoid or minimise negative impacts of developments than it is to create and maximise positive ones. This aligns with the mitigation hierarchy outlined in the EU Biodiversity Strategy (2011) “*No Net Loss Initiative*” and translated into national level policy (e.g. HM Government 2011): the first objective should be to avoid/prevent negative impacts; where this is impossible, damage should be minimised and restoration attempted; compensation or offsetting should be a last resort. Indeed it is important to note that secondary benefits that can be built-in to coastal defence developments, as discussed in this study, are not considered adequate mitigation or compensation for the loss of natural habitats and species caused by construction works. Building-in beneficial features should not, therefore, be prioritised over more sustainable flood and coastal erosion risk management approaches. However, where hard structures are considered

necessary and appropriate for coastal management, then opportunities should be taken to maximise secondary benefits as well as minimising environmental impacts.

All of the considerations and potential secondary benefits evaluated in the Delphi study were put forward as being important by the panel. As such, none were considered unimportant or irrelevant. In general, however, the lowest priority considerations for coastal defence developments (and the secondary benefits that can be built-in to them) were perceived to be the provision of opportunities for education and outreach, and the net cultural and heritage impacts. Although it is widely accepted that direct experiences in nature can promote more environmentally-conscious behaviour (e.g. Kals et al. 1999), it was suggested that there are more appropriate opportunities for engaging the public with the marine environment. However, as one panellist commented, better education and outreach may be necessary to generate community support for more sustainable long-term management strategies. Community involvement in strategic planning has become commonplace in recent years (Ledoux et al. 2005) and in some cases, uninformed citizen-based decisions have led to inappropriate management strategies (Young et al. 2014).

It was pointed out that the absence of representation from the education, culture and heritage sectors on the panel may have biased the overall rankings against these options. This should be acknowledged as a limitation of the study. The panel was constructed so as to balance inclusion of a wide range of relevant sectors with the practicalities of processing responses within a reasonable time frame, and the likelihood of retaining 100% participation throughout the study.

4.2 Proposed steps to implementation of multi-functional coastal defences

As policy and legislation begins to recognise the need for developers to take a more pro-active role in protecting and enhancing the natural environment (e.g. HM Government 2011), our study provides some much-needed clarity on what can be done to deliver secondary ecological and socio-economic benefits from coastal defence developments. Based on findings from the modified Delphi study, we propose a four-step approach to wide-scale and effective implementation of multi-functional coastal

defence developments (Box 4), which will be useful to inform the future direction of research in this field.

It is important to note that we are not starting from the beginning of *Step 1* (gathering evidence; Box 4). A wealth of evidence already exists globally to support methods of enhancing artificial structures for environmental, social and economic benefit (see reviews by Baine 2001, Moschella et al. 2005, Chapman and Underwood 2011, Firth et al. 2014, 2016a, Dafforn et al. 2015). Nevertheless, a lack of evidence that secondary benefits can be realised, and a lack of understanding of the ecology of artificial habitats, were both perceived to be barriers to effective implementation by the Delphi panel. This led to the general consensus that they would be more supportive of multi-functional coastal defence structures *only if evidence can be provided* that the intended benefits will be realised (Box 3). It was pointed out, however, that this obligation to provide evidence may become an unreasonable obstacle to implementation and further experimentation. This echoes previous appeals in the literature (Bulleri and Chapman 2010, Chapman and Underwood 2011, Naylor et al. 2012, Sella and Perkol-Finkel 2015) where it has been argued that implementation, with experimental control and long-term monitoring, is necessary in order to gather further evidence. It will be necessary, therefore, for decision-makers to accept a degree of uncertainty in early practice, to strengthen the evidence base across different environmental contexts and enable greater confidence in decision-making in future.

Another key perceived barrier to implementation was the ability to justify additional costs that may be associated with multi-functionality. Throughout this study, there was considerable discrepancy in opinions regarding the importance of cost. Although financial constraints are often a substantive limitation of conservation efforts globally (McKinney 2002, Balmford et al. 2003, McCarthy et al. 2012), there is increasing recognition of the value of natural capital – the goods and services that can be supported by a healthy natural environment (Costanza et al. 2014). Numerous tools are available for assessing the value of these goods and services (e.g. Mitchell and Carson 1989, Hanley et al. 1998, Carr and Mendelsohn 2003) and the associated costs of protecting them (e.g. Marxan, Ball et al. 2009). But although socio-economic secondary benefits of coastal defence developments may be readily evaluated (e.g. enhanced commercial fishery), further research is necessary (*Step 2*; Box 4) to reliably assess the

non-use value of (and justify additional costs of) potential *ecological* secondary benefits (e.g. provision of habitat for conservation species). The panel acknowledged the challenging financial climate in which flood and erosion risk management decisions are necessarily being made in the UK (Committee on Climate Change 2014), as in other parts of the world (Nicholls and Tol 2006, Hinkel et al. 2013), but also pointed out the potential to attract partnership funding (Defra 2011) from identified beneficiaries of potential secondary benefits. Again, potential sources of partnership funding may be more obvious for socio-economic secondary benefits than for ecological ones, but it was suggested in this study that the beneficiary could conceivably be UK PLC if none more specific could be identified. This implies that benefits to society in general could feasibly attract public funding (see Seattle Seawalls case study described in Naylor et al. 2012 for an example of this).

As stressed by the Delphi panel, any built-in secondary benefits must be designed and evaluated in the context of the local environment and communities in question. They must also be tailored to the requirements of the specific targeted species or services desired. Through further experimental trials, new technologies and products may be developed (*Step 3*; Box 4) to provide a catalogue of off-the-shelf ecological engineering solutions necessary to deliver the range of potential secondary benefits that have been identified (see *Future directions for research* in Bulleri and Chapman 2010). Since so many coastlines have already been artificially hardened globally (Koike 1996, Davis et al. 2002, Chapman and Bulleri 2003, Airolidi and Beck 2007, Firth et al. 2016a), it is important to seek engineering solutions that can be applied retrospectively to existing structures (e.g. Martins et al. 2010, Firth et al. 2014, Browne and Chapman 2014, Evans et al. 2016, Perkol-Finkel and Sella 2016) as well as to investigate multi-functional designs for new developments (e.g. Chapman and Blockley 2009, Jackson et al. 2012, Firth et al. 2014, Dafforn et al. 2015, Scyphers et al. 2015, Sella and Perkol-Finkel 2015, Perkol-Finkel and Sella 2014, 2016).

Box 4. Steps to effective implementation of multi-functional coastal defences

Step 1: Gather evidence of efficacy of secondary benefits

Conduct a systematic evidence-gathering exercise, firstly collating existing evidence from the literature and via knowledge exchange with international partners, and secondly filling any knowledge gaps through experimental trials and targeted surveys.

Step 2: Value secondary benefits

Conduct cost-benefit analyses to make reliable valuations of the net benefits of different engineering options. It may be possible to identify beneficiaries of potential secondary benefits to attract additional partnership funding.

Step 3: Develop new technologies and ecological engineering “products”

Expand existing knowledge of ecological engineering solutions, from high-level design concepts and materials, to off-the-shelf habitat enhancement units tailored to support specific target species and services.

Step 4: Encourage implementation

Facilitate knowledge exchange and uptake to improve awareness and engagement amongst relevant sectors, and to encourage communication about multi-functional options during the planning stage of new developments.

Some Delphi panel members commented that the legislative framework, communication between sectors and awareness of multi-functional structures all exist, despite these being perceived as barriers by others. They instead suggested that what is lacking is the robust evidence needed to drive policy changes and encourage engagement with the concept of multi-functionality. In reality, the greater barrier appears to be a lack of awareness of, or access to, the body of evidence that currently exists. It is unrealistic to expect practitioners across different sectors to keep abreast of the rapidly-expanding body of academic literature in this field (Holmes and Clark 2008). Instead, it may be necessary for researchers to pro-actively facilitate knowledge exchange and uptake through training sessions and practitioner-focused workshops. The role of ‘interpreters’ (Holmes and Clark 2008), ‘boundary

organisations' (McNie 2007) or 'knowledge brokers' (Naylor et al. 2012) has been championed in the science-policy literature. These individuals or organisations 'bridge the gap' between the producers and users of knowledge, to ensure research is more visible and useful to decision-makers (McNie 2007, Holmes and Clark 2008, Naylor et al. 2012). The independent not-for-profit body, CIRIA (the Construction Industry Research and Information Association, www.ciria.org), has emerged as an effective intermediary group in the field of ecological engineering and green infrastructure in the UK (but also operating internationally). If *Steps 1-3* (Box 4) can be achieved, and evidence can be effectively communicated to policy-makers and practitioners, then more specific policies may develop to strengthen the legislative framework in which secondary benefits are considered. This would provide the incentive and confidence required to encourage engagement and communication between sectors about multi-functional options during the planning stage of new developments (*Step 4*; Box 4).

4.3 Conclusions

In this study we conducted a stakeholder perception study, applying a modified Delphi technique to elicit and untangle stakeholder opinions regarding: (i) the most important considerations for planning coastal defence developments; (ii) the potential secondary benefits that can be built-in to coastal defence structures; (iii) the level of support for multi-functional coastal structures; (iv) differences and consensus in perceptions across sector groups; and (iv) the steps necessary to achieve their effective implementation. We identified varying degrees of consensus and conflict between stakeholders from different sectors. There was clearly, however, considerable support for implementing multi-functional coastal defence structures that can deliver secondary benefits – particularly ecological secondary benefits – in place of traditional single-purpose structures. The provision of habitat for rocky shore communities and species of conservation interest, and the provision of refuge for exploited species were ranked overall as the highest priority secondary benefits that could feasibly be delivered by multi-functional structure designs. This is valuable information for informing marine and coastal planning decisions that seek to balance environmental, social and economic priorities. A defining principle for the effective conservation of wild living resources (Mangel et al. 1996) is that it takes account of the motives, interests and values of all users and stakeholders, *but not by simply averaging their positions*.

We found the modified Delphi technique to be an effective means of synthesising information and expert judgements on this complex problem. The findings presented here will support progress towards wide-scale and effective implementation of ecologically-sensitive design of artificial coastal defence structures that are becoming ubiquitous features of urban coastlines. It may further be reasonable to apply these findings to the various other engineered structures – for oil and gas exploration, renewable energy generation, navigation, mariculture and recreation – that are proliferating in the marine environment globally (Dafforn et al. 2015, Firth et al. 2016a).

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